PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in or relating to Aerials

We, ELECTRIC & MUSICAL INDUSTRIES LIMITED, a British company, of Blyth Road, Hayes, Middlesex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to aerials and it relates in particular to helical aerials, which are specially suitable for the radiation or reception of microwave electro-magnetic energy.

It has previously been proposed to provide an aerial for radiating or receiving microwave energy comprising a conductor wound in the form of a helix and associated with a flat ground plane. With a helix of given dimensions the mode of operation and the radiation pattern vary with frequency and several distinct modes of operation of the helical aerial are possible. The helical aerial has the advantage of being able to radiate or receive energy in a wide band of frequencies, and moreover it is of simple construction. However, a problem encountered in the construction of helical aerials is that of providing a support for the helix in order to secure its mechanical rigidity under conditions of vibration. The helical aerial can be supported in a dielectric framework with little or no effect upon the radiation pattern provided the frequency is low, because the supports may be made much smaller than the operating wavelength. However, the applicants have discovered that when the aerial has to operate at microwave frequencies, a supporting device necessarily has dimensions which are not negligible when compared with the operating wavelength and deterioration of the radiation pattern occurs.

An object of the present invention is to reduce the difficulties aforesaid.

According to one aspect of the present invention there is provided a helical aerial in which a helical conductor is enclosed in dielectric material whose cross-sectional dimensions are so chosen that for energy of a predetermined frequency, the phase velocity of propagation in said material in the direction of the axis of said helix approximates to the velocity of a plane wave in an unbounded medium of said material, and the helical conductor is dimensioned (taking into account the dielectric material) for the propagation or reception of a circularly polarised wave of said frequency directed along said axis.

In certain applications of helical aerials, the disadvantage is encountered that the amplitude of side lobes in the radiation pattern is excessive, and with a view to reducing the amplitude of side lobes, a structure is preferably provided to form a ground plane disposed about said conductor and of conical shape or other shape diverging towards the outer end of said conductor.

Preferably, the ground plane is conical and has a total included angle of approximately 90°, is coaxial with the longitudinal axis of the aerial and has an aperture of approximately λ or greater where λ is the free space wavelength of the centre frequency to be radiated or received. However the sides of the ground plane need not be straight either locally or along their full length.

In order that the invention may be clearly understood and readily carried into effect, the invention will be described with reference to the accompanying drawings, in which:—

Figure 1 illustrates a form of a helical aerial in accordance with the present invention, and

Figure 2 illustrates diagrammatically a modification of Figure 1 designed for operation at higher frequencies than the aerial of Figure 1.

Referring to the drawing, Figure 1 shows a helical aerial designed to radiate in the first axial mode in a frequency band centred at, say, 4000 Mc/s. The aerial comprises a metal helix 1 which has for example four turns and is clockwise wound looking from the free end of the helix. The right-hand end of the helix, as shown in the drawing, is connected to the inner conductor 2 of a coaxial feeder for the energy to be radiated or received by the aerial. The outer conductor of the coaxial feeder, a fragment of which is shown at 3 in the drawing, is connected to a metal cone 4 which is

coaxial with the helix 1 and serves as the ground plane of the aerial. The coaxial feeder may be disposed as shown or on the axis of the helix. In order to support the helix to ensure rigidity under conditions of vibration, the helix 1 is wholly enclosed in a cylindrical sleeve 5 of a dielectric material, which is polythene in the present example, whilst a cylindrical core of the same dielectric material is inserted into the interior of the helix. This core is shown dotted in Figure 1 and is denoted by the reference 6. Instead of employing a mount in the form of the sleeve 5 and core 6, the helix 1 may be embedded partly or completely in a moulded dielectric mount having external dimensions corresponding to those of the sleeve 5. The mount is secured to the cone 4, and hence to the aerial support, in any suitable manner.

The aerial shown in Figure 1 is intended for propagating radiation mainly along the axis of the helix as a circularly polarised wave. The fact of the helix being enclosed in dielectric material tends however to cause the aerial to take up some of the characteristics of a dielectric guide aerial, as a result of the dielectric material acting as a guide for the electrical radiation along its length. The phase velocity of propagation along the dielectric and also the ratio of power guided inside to that guided outside are functions of the diameter of the mount formed by the sleeve 5 and the core 6, the wavelength of the radiation, and the dielectric constant k of the material of which the mount is made. The diameter of the mount is arranged to be of the order of half the wavelength at the centre frequency of the frequency band of the aerial. It may be shown that, on this condition, the phase velocity of propagation in the mount in the direction of the axis of the helix approximates to the velocity of a plane wave in an unbounded medium of the material and deterioration of the radiation pattern compared with that which could be obtained from a helix in free space is relatively small. It is of course necessary to adjust the dimensions of the helix compared with those of a helix in free space designed to produce the same radiation pattern in the same frequency band. For example a helix operating in free space and working in the aforesaid frequency band centred at 4000 Mc/s, may have a pitch of about 0.72 inches and an external diameter of 0.93 inches whereas for the helix enclosed in the dielectric mount 5, 6, the dimensions are reduced in the ratio of $\sqrt{k}:1$. For the case in which the dielectric material is polythene this requires that the pitch of the helix be reduced to about 0.48 inches and its diameter to about 0.62 inches. When the helix dimensions are of this order, the aerial was found to have a radiation pattern similar to that of a helix of the aforesaid larger dimensions and mounted in free space. Direction of rotation of the electrical vector of the propagated wave depends on whether the helix is wound clockwise or counter clockwise.

The cone 4 has an angle of 90° and an aperture of about λ where λ is the wavelength in free space at the aforesaid centre frequency. In a practical case the dimensions of the cone may be determined empirically to obtain the maximum reduction of the side lobe amplitude in the radiation pattern. In the present example, the cone aperture is approximately 3.0 inches. The ground plane need not however be of exact conical form, and other shapes which diverge towards the free end of the helix may be used.

Figure 2 illustrates a further form of the aerial in accordance with the present invention, designed for operation in the X band, that is at frequencies of the order of 10000 Mc/s. The aerial is essentially of the same construction as shown in Figure 1 and corresponding parts are denoted by the same reference numerals, the dimensions being however reduced in the correct ratio to suit the higher operating frequency. The helix has about 4½ turns and is clockwise wound. The diameter of the helix is about 0.29 inches, the pitch about 0.22 inches and the thickness of the wire of the helix about 0.04 inches. The diameter of the polythene core is about 0.25 inches, the polythene sleeve has a thickness of 0.09 inches, and the length of the sleeve is about 1 inch. The aperture diameter of the cone is about 1.32 inches. The construction shown in Figure 2 is, however, modified as compared with Figure 1 as regards the lead-in to the helix through the cone. The cone is mounted directly on a length of waveguide 7 and a probe 9 projects from the inner end of the helix into the guide through a polythene plug 8 at the apex of the cone. A movable piston 10 is located at one end of the guide in order to facilitate impedance matching of the probe from the helix into the guide.

While the invention has been described as applied to aerials operating at frequencies of the order of 4000 Mc/s and higher aerials in accordance with the invention may also be used for the transmission and reception of television and sound programmes at high frequencies. For such use, the aerials have the advantage of broad band width, which may be of the order of 25 per cent or more of the centre frequency of the band, and the gain of the aerial is high. The aerial can also receive signals radiated with horizontal or vertical polarisation. Moreover, the transmission of circularly polarised waves for omni-directional broadcast purposes can be obtained by using four helical aerials radiating at 90° intervals, thereby giving all round coverage.

What we claim is:—

1. A helical aerial in which a helical conductor is enclosed in dielectric material whose cross-sectional dimensions are so chosen that for energy of a predetermined frequency, the

phase velocity of propagation in said material in the direction of the axis of said helix approximates to the velocity of a plane wave in an unbounded medium of said material, and the helical conductor is dimensioned (taking into account the dielectric material) for the propagation or reception of a circularly polarised wave of said frequency directed along said axis.

2. A helical aerial according to Claim 1, comprising a structure arranged to form a ground plane disposed about said conductor and of conical shape, or other shape diverging towards the outer end of said conductor.

3. An aerial according to Claim 2, wherein said ground plane has a total included angle of approximately 90°.

4. A helical aerial according to Claim 2 or 3 wherein the aperture of said ground plane is approximately λ or greater where λ is the free space wavelength at a predetermined frequency to be radiated or received.

5. A helical aerial substantially as herein described with reference to the drawings.

A. B. LOGAN,
Chartered Patent Agent.

PROVISIONAL SPECIFICATION

Improvements in or relating to Aerials

We, ELECTRIC & MUSICAL INDUSTRIES LIMITED, a British company, of Blyth Road, Hayes, Middlesex, do hereby declare this invention to be described in the following statement:—

This invention relates to aerials and it relates in particular to helical aerials, which are specially suitable for the radiation or reception of microwave electro-magnetic energy.

It has previously been proposed to provide an aerial for radiating or receiving microwave energy comprising a conductor wound in the form of a helix and associated with a flat ground plane. With a helix of given dimensions the mode of operation and radiation patterns vary with frequency and several distinct modes of operation of the helical aerial are possible. The helical aerial has the advantage of being able to radiate or receive energy in a wide band of frequencies, and moreover it is of simple construction. However, for certain applications, the amplitude of side lobes in the radiation pattern is excessive, and one aspect of the present invention is to reduce the amplitude of side lobes.

According to this aspect of the present invention there is provided a helical aerial which has a ground plane in the general form of a cone or conical shape about the aerial.

Preferably, the cone has a total included angle of approximately 90°, is coaxial with the longitudinal axis of the aerial and has an aperture of approximately 1.0λ where λ is the free space wavelength of the centre frequency to be radiated or received.

Another problem encountered in the construction of helical aerials is that of providing a support for the helix in order to secure its mechanical rigidity under conditions of vibration. The helical aerial can be supported in a dielectric framework with little or no effect upon the radiation patterns provided the frequency is low, because the supports may be made much smaller than the operating wavelength. However, the Applicants have discovered that when the aerial has to operate at microwave frequencies the supporting device has dimensions which are not negligible when compared with the operating wavelength and deterioration of the radiation patterns occur.

The object of another aspect of the present invention is to reduce the difficulties aforesaid.

According to this other aspect of the present invention there is provided a helical aerial in which the helix is enclosed in dielectric material and the linear dimensions of the helix are reduced approximately by a factor of $\sqrt{k}$ compared with the dimensions which the helix would have if located in free space, where k is the dielectric constant of the supporting dielectric material.

In order that the invention may be clearly understood and readily carried into effect, the invention will be described with reference to the accompanying drawings, in which:—

Figure 1 illustrates one form of a helical aerial in accordance with the present invention.

Figure 2 illustrates another form of a helical aerial in accordance with the present invention, and

Figure 3 illustrates diagrammatically a modification of Figure 2 designed for operation at very high frequencies.

Referring to the drawing, Figure 1 shows a helical aerial constructed in accordance with the first aspect of the present invention, the aerial being designed to radiate in the first axial mode in a frequency band centred at, say, 4000 Mc/s. The aerial comprises a metal helix 1 which has, say, four turns and is clockwise wound. The right-hand end of the helix, as shown in the drawing, is connected to the inner conductor 2 of a coaxial feeder for feeding the energy to be radiated or received by the aerial. The outer conductor of the coaxial feeder, a fragment of which is shown at 3 in the drawing, is connected to a metal cone 4 which is coaxial with the helix 1 and serves as the ground plane of the aerial. The helix has a pitch of about 0.72 inches and an external diameter of about 0.93 inches. The cone 4 has an angle of 90° and an aperture of

about 1.0λ where λ is the wavelength in free space at the aforesaid centre frequency. The dimensions of the cone were determined empirically to obtain the maximum reduction of the side lobe amplitude in the radiation patterns. If an aerial such as that shown in Figure 1 is used for transmission, the radiation is propagated largely along the axis of the helix as a circularly polarised wave and the direction of rotation of the electric vector of the wave depends on whether the helix is wound clockwise or counter clockwise.

Figure 2 of the drawing shows a modification of Figure 1 in which, in order to support the helix to ensure rigidity under conditions of vibration, the helix 1 is wholly enclosed in a cylindrical sleeve 5 of a dielectric material, which is polythene in the present example, whilst a cylindrical core of the same dielectric material is inserted into the interior of the helix. This core is shown dotted in Figure 2 and is denoted by the reference 6. Instead of employing a mount in the form of the sleeve 5 and core 6, the helix 1 may be embedded in a moulded polythene mount having external dimensions corresponding to those of the sleeve 5. The effect of enclosing the helix in dielectric tends to cause the aerial to take up some of the characteristics of a poly-rod antenna, as a result of the dielectric material acting as a guide for the electrical radiation along its length. The phase velocity of propagation along the dielectric and also the ratio of power guided inside to that guided outside are functions of the mount diameter, wavelength of the radiation and the dielectric constant k of the dielectric material of which the mount is made. It may be shown that if the diameter of the mount is of the order of half the wavelength then the phase velocity in the mount is nearly the same as in an unbounded medium of the dielectric. On this basis, to ensure that substantially the same phase relationship prevails for the aerial of Figure 2 as for the aerial of Figure 1 operating in free space, compensation is made for the effect of the changed medium. In accordance with the invention this is done by reducing the dimensions of the helix 1 in the ratio of $\sqrt{k}:1$. For the case in which the dielectric material is polythene, this requires that the pitch of the helix be reduced to about 0.48 inches and its diameter to about 0.62 inches. When the helix dimensions are modified in this way, the aerial illustrated in Figure 2 was found to have radiation patterns similar to that shown in Figure 1.

Figure 3 illustrates a further form of the aerial in accordance with the present invention, designed for operation in the X band, that is at frequencies of the order of 10000 Mc/s. The aerial is essentially of the same construction as shown in Figure 2 and corresponding parts are denoted by the same reference numerals, the dimensions being however reduced in the correct ratio to suit the higher operating frequency. The helix has about 4¼ turns and is clockwise wound. The diameter of the helix is about 0.29 inches, the pitch about 0.22 inches and the thickness of the wire of the helix about 0.04 inches. The diameter of the polythene core is about 0.25 inches, the polythene sleeve has a thickness of 0.09 inches, and the length of the sleeve is about 1 inch. The aperture diameter of the cone is about 1.32 inches. The construction shown in Figure 3 is, however, modified as compared with Figures 1 and 2 as regards the lead-in to the helix through the cone. The cone is mounted directly on a length of waveguide 7 and a probe 9 projects from the inner end of the helix into the guide through a polythene plug 8 at the apex of the cone. A movable piston 10 is located at one end of the guide in order to facilitate impedance matching of the probe from the helix into the guide.

While the invention has been described as applied to aerials operating at frequencies of the order of 4000 Mc/s and higher, aerials in accordance with the invention may also be used for the transmission and reception of television and sound programmes at high frequencies. For such use, the aerials have the advantage of broad band width, which may be of the order of 25 per cent the centre frequency of the band, and the gain of the aerial is high. The aerial can also receive signals radiated with horizontal or vertical polarisation. Moreover, the transmission of circularly polarised waves for broadcast purposes can be obtained by using four helical aerials radiating at 90° intervals, thereby giving all round coverage.

F. W. CACKETT,
Chartered Patent Agent.

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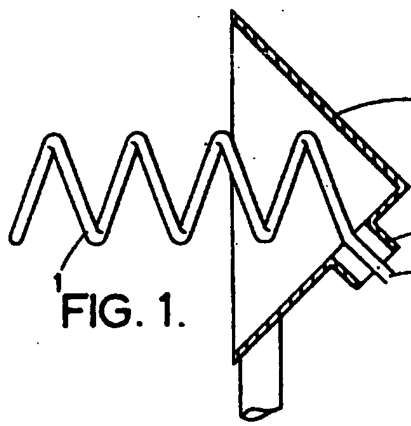

FIG. 1.

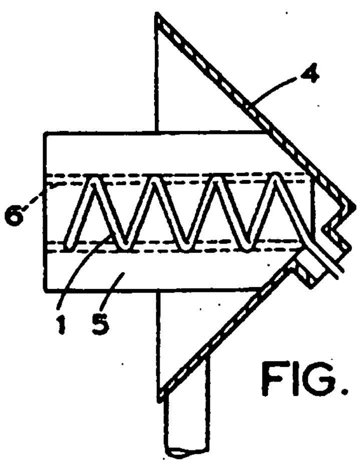

FIG. 2.

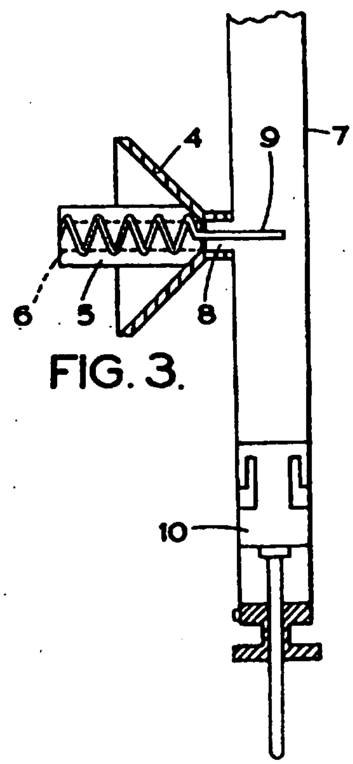

FIG. 3.

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1 SHEET

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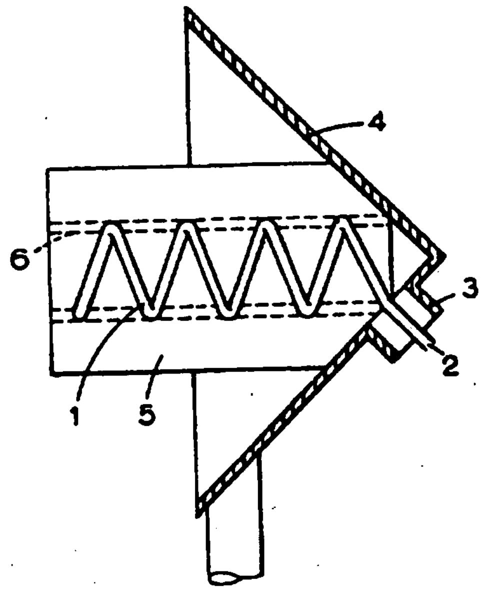

FIG. 1.

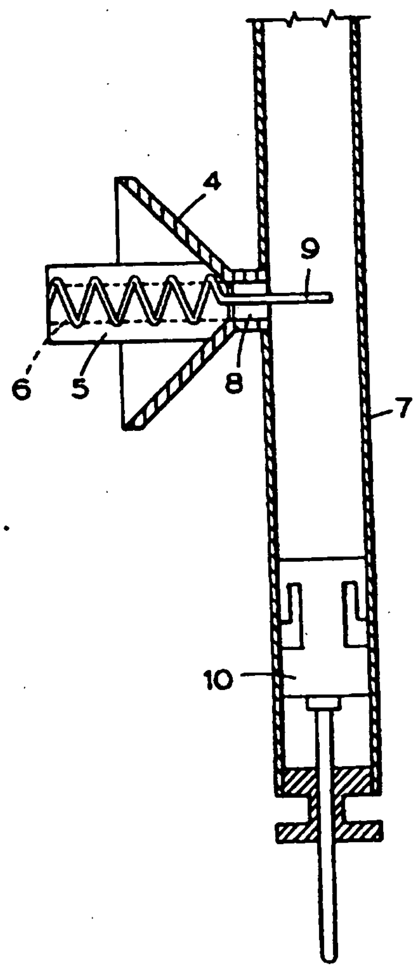

FIG. 2.